Water balance of the Arctic drainage system using GRACE gravimetry products

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Table 1: Surface of the largest Arctic drainage basins (ArcticRIMS, 2003), mean annual discharges (CAFF, 2001), and availability of the discharges data at the closest station to the mouth.

Basin	Surface (km^2)	Mean annual discharge ($km^3 yr^{-1}$)	Availability of river discharges at the closest station to the mouth
Yukon	833232	210	Not available
Mackenzie	1783972	340	2002 – 2005
Nelson	1106578	75	Not available
Severnyy Dvina	448664	110	1881 - 2009
Pechora	321731	140	1916 -1998
Ob	2994238	530	1936 - 2009
Yenisey	2537404	603	1936 - 2009
Kotya (Kathanga)	372001	105	Not available
Lena	2460742	525	2000 - 2009
Indigirka	324244	57	1936 -1998
Kolyma	651631	132	1978 - 2009

Table 2: Spatial and temporal resolutions, and period acquisition of the GRACE-derived SWE and of the datasets used for comparisons.

Dataset	Spatial resolution	Temporal resolution	Acquisition period
GRACE-derived SWE	400 km	monthly	2002-2007
USAF/ETAC snow depth climatology	1°	monthly	1950s-1980s
EWG snow depth climatology	250 km	monthly	1966-1982
CMS SWE climatology	0.25°	monthly	1979-1997
GPCP-derived snowfall	1°	monthly	2002-2007

Table 3: Correlation and time lag between GRACE-derived SWE and snowfall derived from GPCP by river basin.

GRACE/GPCP	Corr	Time lag
Yukon	0.75	2
Mackenzie	0.76	2
Nelson	0.11	0
Severnyy Dvina	0.57	1
Pechora	0.7	2
Ob	0.68	1
Yenisey	0.6	1
Kotya (Kathanga)	0.39	2
Lena	0.45	1
Indigirka	0.38	1
Kolyma	0.44	1

Table 4: Correlation and time lag between fresh water volume and snow stored for the different remote sensing datasets by river basin.

Correlation | Time lag (months)	Kolyma	Lena	Mackenzie	Ob	Pechora	Svernaya Dvina	Yenisey
GRACE (Land)/Dis	0.39 | 2	0.38 | 3	0.66 | 3	0.65 | 3	0.43 | 2	0.60 | 2	0.39 | 3
GRACE (Snow)/Dis	0.49 | 3	0.73 | 4	0.77 | 4	0.8 | 4	0.51 | 3	0.62 | 2	0.52 | 4

Table 5: Correlation between TWS and P-E by river basin.

Correlation	TWS/P-E
Yukon	0.48
Mackenzie	0.68
Nelson	0
Severnaia Dvina	0.51
Pechora	0.51
Ob	0.7
Yenisey	0.57
Kotya (Kathanga)	0.18
Lena	0.24
Indigirka	0.15
Kolyma	0.17

Table 6: Trends of snow volume, TWS volume and water volume to the Arctic Ocean (when data are available) estimated between 2003 and 2006 by river basin.

Trend (km^3yr^{-1})	SWE (GRACE)	TWS (GRACE)	Discharge	PGR
Yukon	(1.8 ± 0.7)	(-7.3 ± 0.6)	x	-0.01
Mackenzie	(10.9 ± 1.0)	(18.5 ± 1.0)	(0.5 ± 0.5)	25.60
Nelson	(0.7 ± 0.2)	(4.5 ± 0.2)	x	18.80
Severnaia Dvina	(-4 ± 0.4)	(-6.4 ± 0.4)	(-1.6 ± 0.2)	0.26
Pechora	(-2 ± 0.3)	(-4.1 ± 0.3)	x	-0.18
Ob	(-5.7 ± 1.4)	(-10 ± 1.6)	(-0.8 ± 0.5)	-0.96
Yenisey	(-1.1 ± 1.4)	(7.9 ± 1.2)	(0.5 ± 1.5)	-0.77
Kotya (Kathanga)	(-2.1 ± 0.2)	(0.8 ± 0.2)	x	-0.13
Lena	(8.6 ± 0.9)	(13.6 ± 0.9)	(4.4 ± 0.9)	-0.59
Indigirka	(0.1 ± 0.1)	(1.1 ± 0.2)	x	-0.17
Kolyma	(-1.2 ± 0.3)	(3.4 ± 0.3)	x	-0.31

Figure 1: Location of the main Arctic drainage basins and their annual discharge (km^3yr^{-1}). Source: Major River Systems in the Arctic. UNEP/GRID-Arendal Maps and Graphics Library. 2002. Available at: http://maps.grida.no/go/graphic/major_river_systems_in_the_arctic.

Figure 2: Maps of SWE amplitude of annual cycle derived from GRACE over the 2003-2006 period (a), mean annual snow depth from the ETAC monthly snow climatology (b), mean annual snow depth from the EWG monthly snow climatology (c) and total annual snowfall derived from GPCP rainfall over the 2003-2006 period (d).

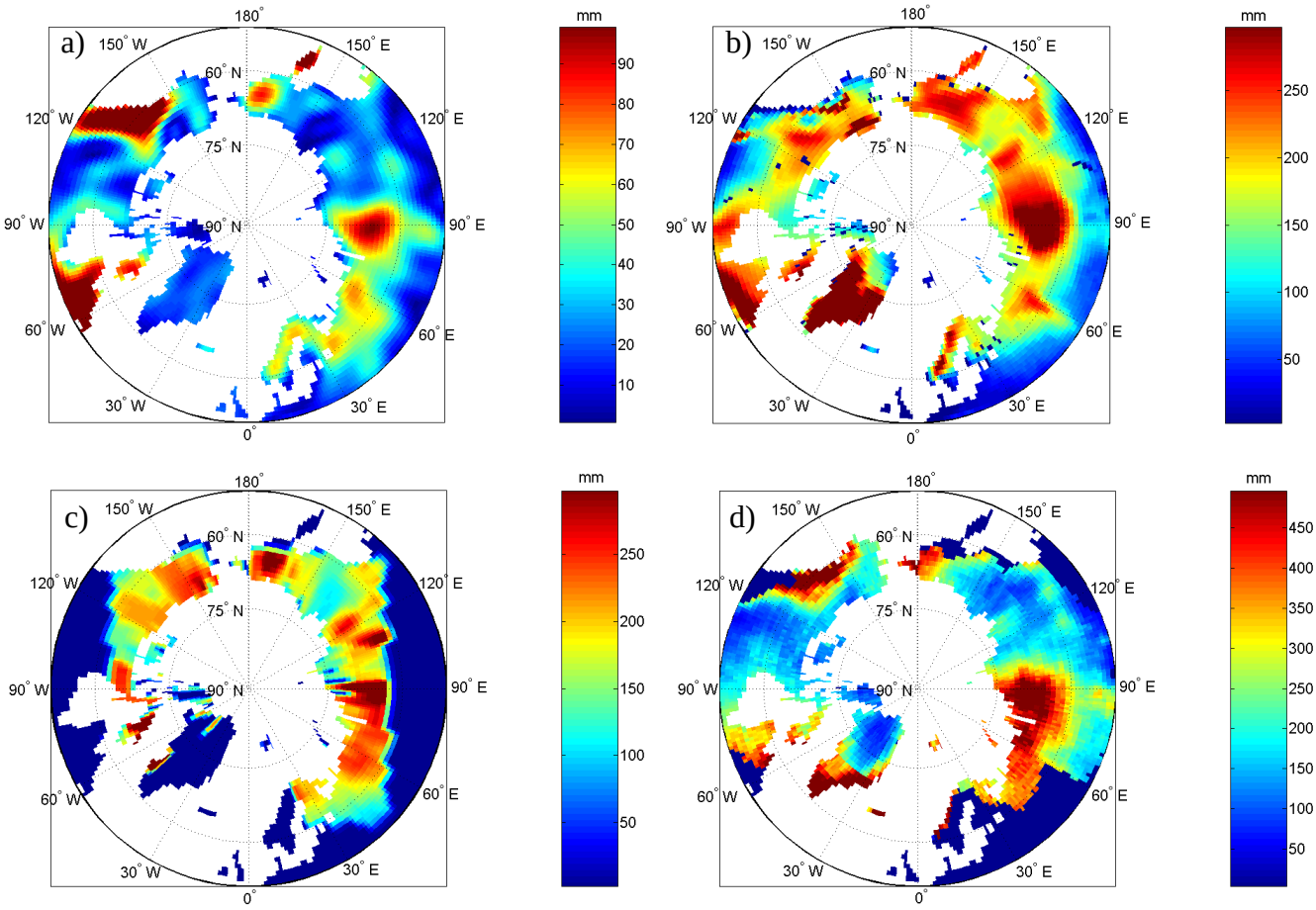

Figure 3: Month where is maximum the GRACE-derived SWE (a), the snow depth from USAF/ETAC climatology (b), and the snow depth from EWG climatology (c).

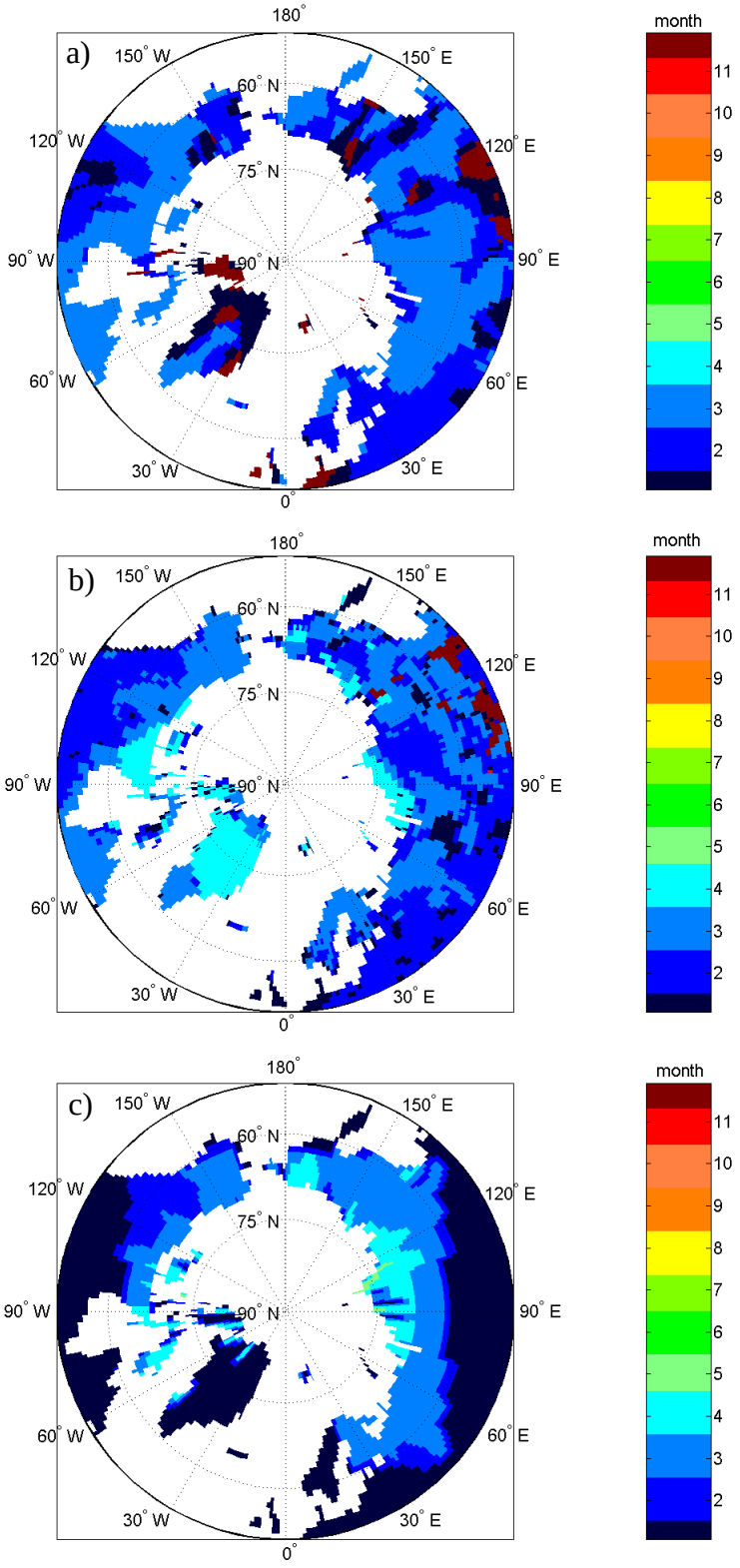

Figure 4: Maps of SWE annual cycle derived from GRACE during the 2003-2006 period (a), mean annual SWE snow climatology (b) over North America. Corr=0.58.

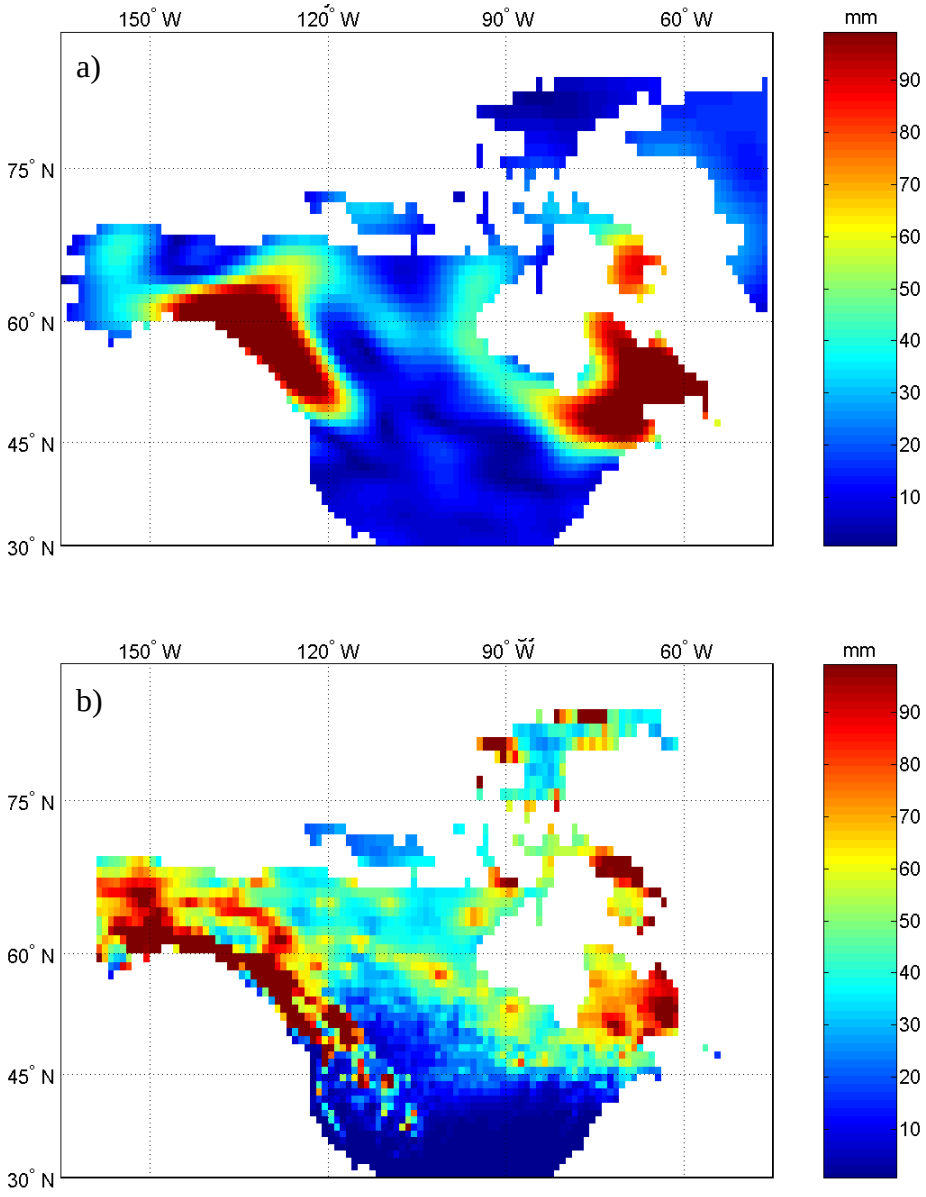

Figure 5: Time series of SWE (mm) derived from GRACE (continuous black) and snowfall (mm) derived from GPCP (dashed black) for the four largest Arctic drainage basins: Ob (a), Yenisey (b), Lena (c), Mackenzie (d).

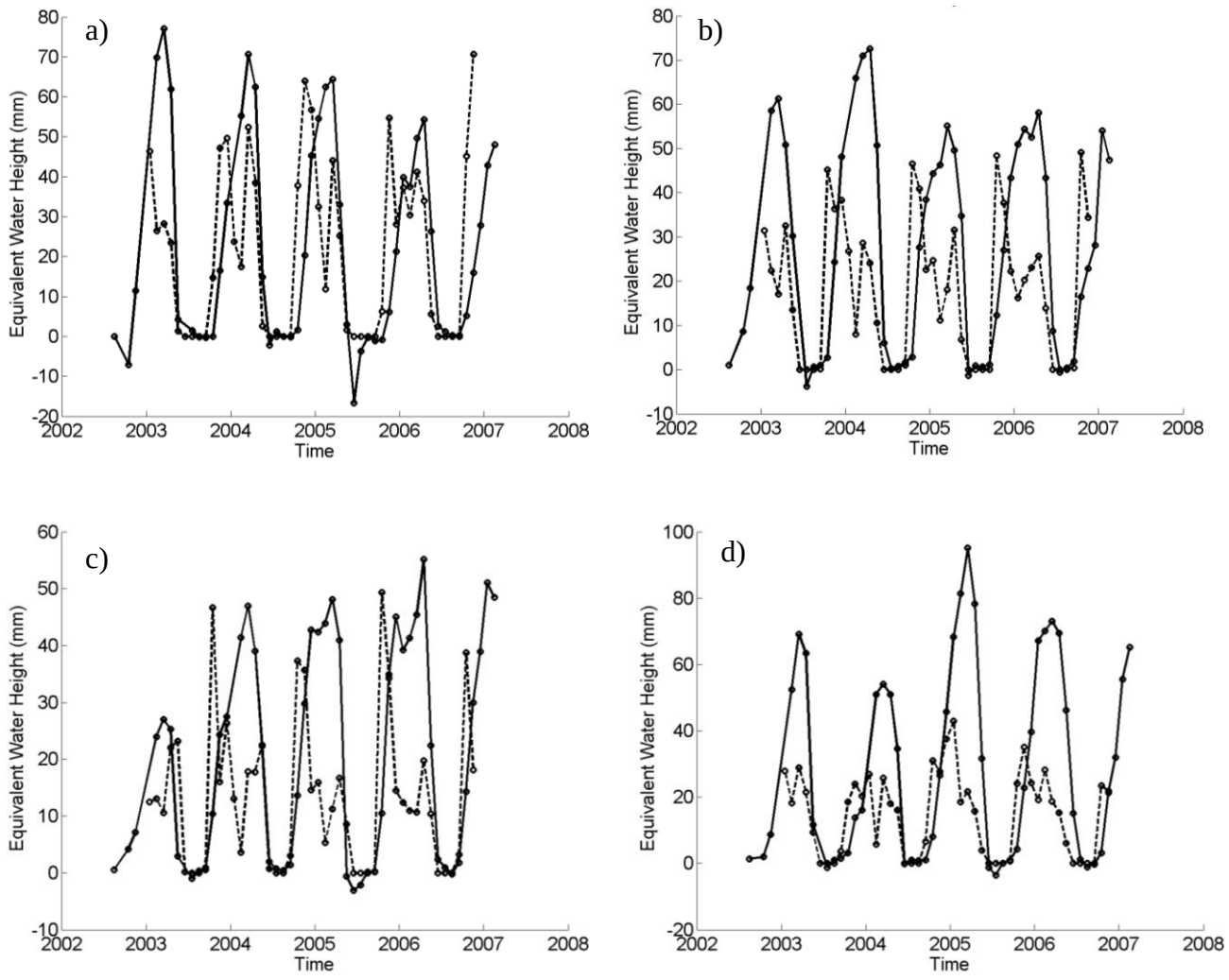

Figure 6: Time series of SWE (mm) derived from GRACE (black) and WGHM (dotted black) for the Nelson (a) and Indigirka (b) basins.

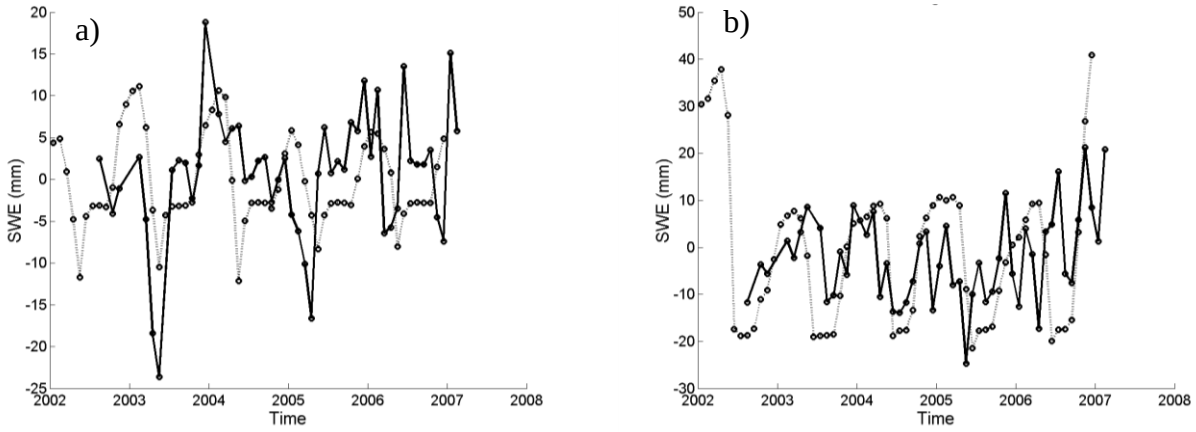

Figure 7: Time series of SWE (mm) derived from GRACE (red), of TWS derived from GRACE (black) and of river discharges (blue) for the six Arctic drainage basins: Ob (a), Yenisey (b), Lena (c), Mackenzie (d), Kolyma (e) and Severnaya Dvina (f).

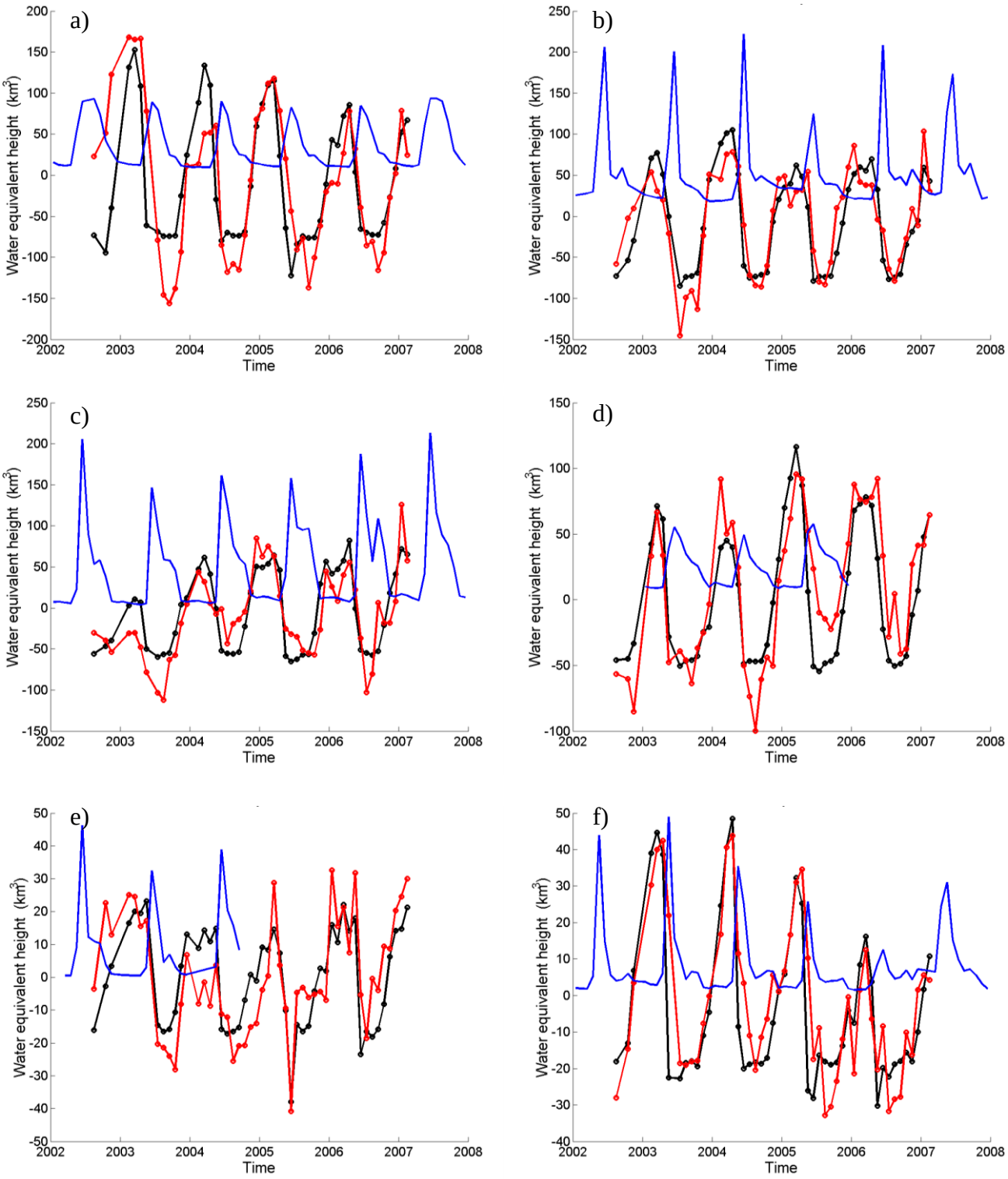

Figure 8: Time series of annual maximum of SWE (mm) derived from GRACE (black) and total annual discharge (10^3 $m^3.s^{-1}$, dotted black) for the Ob (a), Yenisey (b), Lena (c) and Severnaia Dvina (d) basins.

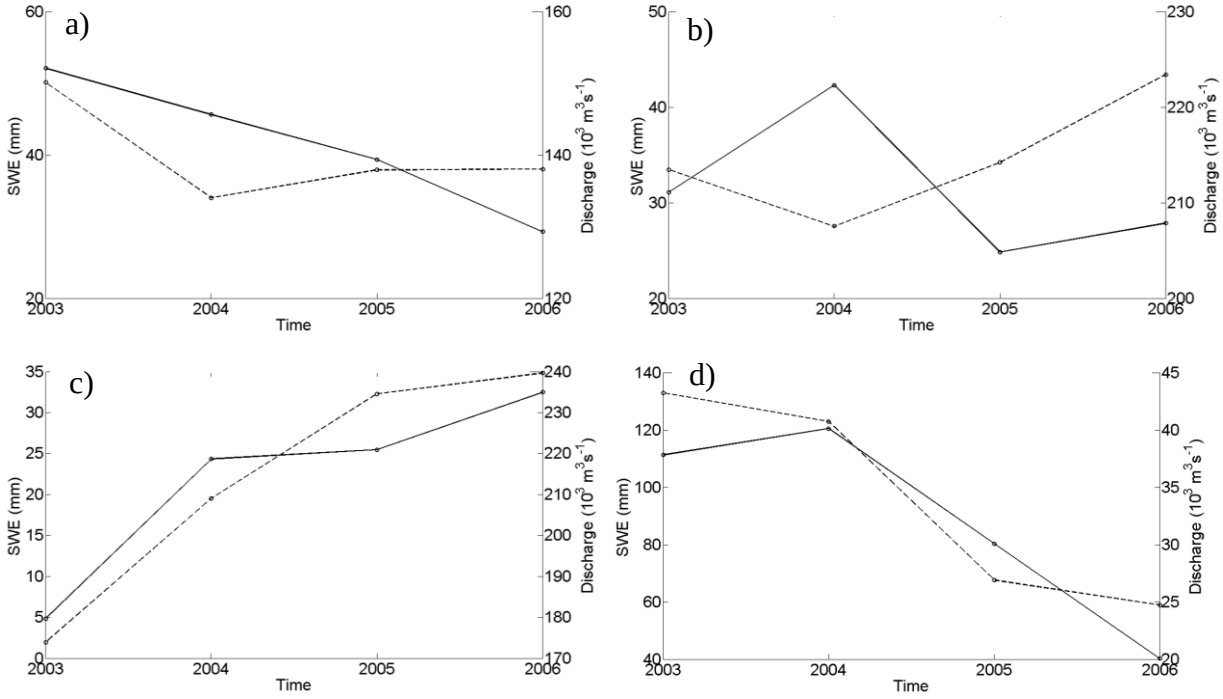

Figure 9: Time series of monthly TWS change (mm/month) derived from GRACE (black) and P-E (dotted black) for the Ob (a), Yenisey (b), Lena (c), Mackenzie (d), Nelson (e) and Yukon (f) basins.